of some molecules, that have rebounded outward, before the next collision takes place, and turn them back on elliptical curves toward the earth. When, with still further ascent, the air grows attenuated enough, these outward flights and returns without collision come to be the dominant feature. The whole summit of the atmosphere is a mass of vaulting molecules, describing loops of all forms, dimensions, and directions. This zone extends from the collisional zone to the outer limit of the sphere of control; some of the vaulting molecules will reach the limit of the sphere, some will go beyond, but the greater multitude will fall short by various degrees. It is wise to emphasize the extremely scattered state of the krenal molecules, especially in the outermost part of the zone, but it is an error to ignore their existence or their importance for many problems. The krenal zone, because of its extreme attenuation, may be called an ultra atmosphere.

The orbital zone.—Collisions are certain to take place in the krenal zone, and by the laws of probabilities the rebounds will in some cases be such that the molecules will then move more or less parallel to the surface of the earth, and a certain proportion of these will have velocities such as to carry them into stable orbits about the earth, in which they will circulate indefinitely until by chance another collision is suffered. An orbital ultra-atmosphere is thus established in the outer portion of the sphere of control: evidently such a condition can not exist in the collisional zone nor in the denser parts of the krenal zone.

A vaulting molecule endowed with the parabolic velocity will, if suffering no collision, go out of the sphere of control and enter into an orbit about the sun; but collisions suffered by orbital molecules may so modify the orbits as to send some of these molecules out of the sphere also, and these modifications may be brought about by a series of successive, relatively insignificant, changes in the orbits. Molecules lost to the earth in the latter way must again pass through the point of collision and in so doing may eventually be captured again by another fortuitous collision; furthermore, the krenal and orbital phases of the solar atmosphere envelop the atmospheres of all the planets; the earth may gain molecules which never before belonged to it, by collisions between solar molecules and molecules of the ultra atmosphere through which they are passing. An equilibrium tends to be established between the ultra-atmospheres of the planets and the sun, for if one becomes more plethoric than is concordant with its relations to the other, it will feed more into the leaner than it will gain from the leaner.

Serious corrections are thus necessary to the current ideas as to the origin, retention, and loss of planetary atmospheres as set forth by Stoney.[1]—*E. W. W.*

[1] See Milham, *Meteorology*, 1914, pp. 15–16; Hann, *Lehrbuch*, 3d ed., 1914, p. 2; Young-*General Astronomy*, 4 Rev. ed., 1904, pp. 181–182; Stoney, *Transactions of the Royal Dublin Society*, 1892, 1897, and 1898, and *Astrophysical Journal*, 11, 36, 1900; *ibid.*, 11, 251, 1900; *ibid.*, 11, 325, 1900; *ibid.*, 12, 201, 1900.

ON THE TEMPERATURE OF THE UPPER STRATA OF THE ATMOSPHERE.

By V. BJERKNES.

[Abstracted from Comptes Rendus, Paris Academy, vol. 170, pp. 747-750, Mar. 22, 1920.]

Upon passing from the troposphere into the stratosphere there is encountered an inversion of temperature, and air movements which are very feeble relative to the surface of the earth; it is easy to find the differential equation of such a surface of discontinuity at which the density of the air and the angular velocity around the axis of the earth both change suddenly. This equation shows that if the density changes, but not the velocity, the surface will coincide with an isobaric surface. In the case of the tropopause, the density of the lower layer is greater than that of the upper; and the angular velocity of the stratosphere does not differ greatly from that of the earth, while that of the upper strata of the troposphere is much greater except in a narrow zone on each side of the Equator and possibly at the poles; hence it comes about that the surface of separation is more flattened along the polar diameter than are the isobaric surfaces of the troposphere, these latter in turn being more flattened than the "level" surfaces, and therefore the tropopause is found at a higher level near the Equator than near the poles.

Similarly, it is easily seen that the angular velocity of the air in a cyclone is greater, and that of the air in an anticyclone is less, than the component of the angular velocity of the earth about the same axis; cyclones and anticyclones being local formations not extending into the stratosphere, it follows[1] that in the highest parts of a cyclone the temperatures will be greater, and in the highest regions of an anticyclone they will be lower, than elsewhere at the same levels; and from the equation referred to above it appears that the tropopause has a depression above a cyclone and an elevation above an anticyclone; these elevations and depressions are not the causes of the formations, but merely the effects of the air movements.[2]—*E. W. W.*

WINDS AND TEMPERATURE GRADIENTS IN THE STRATOSPHERE.[1]

By G. M. B. DOBSON.

[Abstracted from Quar. Jour. Roy. Met'l. Soc., Jan., 1920, 46; 54–64.]

Some years ago observations by "ballons-sondes" showed that while the troposphere is colder in cyclones than in anticyclones, the reverse is the case in the stratosphere, and it was pointed out that as a consequence of this the wind velocity must be reduced in the lower part of the stratosphere. Data obtained from 70 cases where "ballons-sondes" had been followed by theodolites to heights well within the stratosphere and had given satisfactory temperature and pressure records were plotted, *heights being referred to the tropopause, thus causing the elimination of effects due to the variation in the height of the base of the stratosphere above mean sea level.* The resulting diagrams show very clearly that which is not shown when heights are referred to mean sea level, viz, the remarkable suddenness of the changes which take place at the tropopause.

The wind velocity within the troposphere increases with height at a rate roughly inversely proportional to the density, i. e., at a rate which would occur if the pressure gradient remained constant. It may be taken as a general rule that whenever the velocity is fairly large, say, 15 m/s, in the troposphere, it almost invariably decreases very suddenly within the stratosphere; for winds under

[1] *C. R.*, 170, 604, 1920.

[2] J. V. Sandstrom has considered the same questions, and by a less direct analysis has been led to the same conclusions; see Ueber die Beziehung zwischen Temperatur und Luftbewegungen in der Atmsophare unter stationaren Verhaltnissen, Ofversigt af k. Vetenskaps Akkademien Forhandlinger, Stockholm, 1901; and Ueber die Temperaturwerteilung in den aller hochsten Luftschichten, Arkiv. for Math., Astr. och Fysik, Stockholm, 1907. On the physical causes of the occurrence and position of the tropopause, see W. J. Humphreys, Physics of the Air, and in another form in MONTHLY WEATHER REVIEW, 1919; 47, 162–163, and Science, 49, 156–163, 1919.

[1] Cf. a shorter abstract in the REVIEW, Jan. 1920, 48: 11.

10 m/s there seems to be little change, some of them even increasing slightly within the stratosphere (see fig. 1). As soon as the surface layers are left behind the wind direction becomes remarkably constant and remains nearly the same from 4 kilometers up to the highest point reached—no effect is seen in the direction on entering the stratosphere. The horizontal pressure and temperature gradients were computed from the winds on a few typical days, according to the procedure given in the *Computer's Handbook*. The resulting curves show that the horizontal pressure gradient remains nearly constant through-

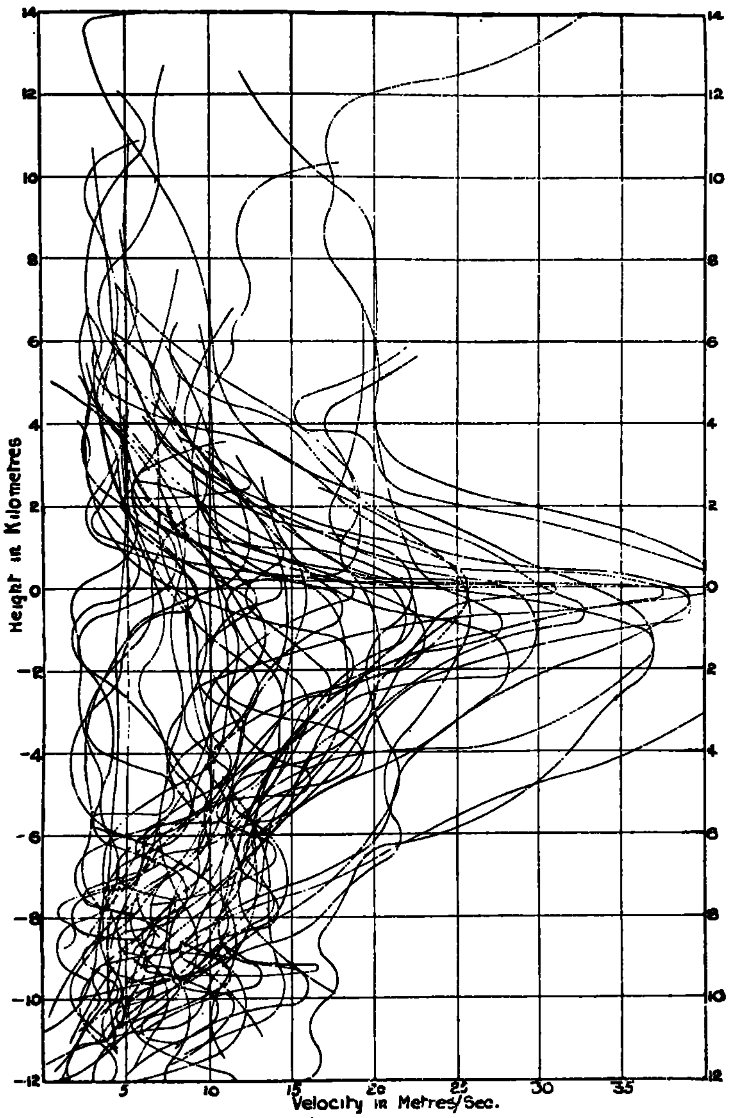

FIG. 1.—Variation of wind velocity with height. (Heights are taken relative to the base of the stratosphere as given by temperature records.)

out the troposphere but suddenly begins to decrease with remarkable rapidity as soon as the tropopause is passed, and approaches zero at about 18 or 20 kilometers; however, even if the pressure gradient never increased above the value shown at the highest level for which results were available, the decrease in density would account for winds of considerable velocity. Within the troposphere the horizontal temperature gradient at right angles to the average direction of the wind increases gradually with height, the air being colder over the cyclone than over the anticyclone, but on entering the stratosphere a very sudden and large reversal takes place and the gradient changes to a value somewhat greater than that at the top of the troposphere, and in the reverse direction; after a kilometer or two this value decreases again and becomes very nearly zero at heights of 18 or 20 kilometers.—*E. W. W.*

ON AN APPARATUS FOR THE STUDY OF THE FORMATION AND PERSISTENCE OF FOG.

By A. TRILLAT and M. FOUASSIER.

[Abstracted from *Comptes Rendus, Paris Acad.*, Mar. 17, 1919, pp. 570–572.]

The condensation of water vapor in the air depends not only upon the quantity of vapor and the changes of temperature, but also upon whether the particles are solid, liquid, or ionized. These factors have been studied principally by Coulier, Mascart, Aitken, Wilson, and Langevin. The present studies were made during the war to devise, if possible, some apparatus which could be employed in forecasting the possibilities of fog. The work rested upon two premises: First, that the possibility of fog in air of given temperature, pressure, and humidity depends chiefly upon the more or less persistent presence of solid or liquid particles; and, second, the expansion necessary to provoke the appearance of fog is less when the number of active particles in the air is great.

The instrument as described in an abstract by R. Corless[1] is as follows: "The apparatus consists of a closed glass vessel of 10 liters capacity, provided with an exhausting pump and a mercury manometer; also with a device for noting when fog of a standard quality has been produced. The air to be tested having been introduced into the vessel, the pressure inside is reduced by means of the pump until the standard fog is produced. The reading of the manometer then gives a measure of the difficulty of production of fog."

The nuclei provided by smoke from the combustion of vegetable and animal products were found to be especially active.

Ammonium salts, magnesium chloride, and emanations of mineral acids possess to a great degree the property of condensing atmospheric moisture about them. On the other hand, the carbonates, silicates, and oxide of iron, which constitute a large proportion of atmospheric dust are less active and less persistent in forming fog. Microorganisms are also effective as nuclei. Some particles are soluble and some insoluble in water vapor, the first appearing to form the more persistent fogs. These experiments, it is pointed out, may explain the difference in the persistence of fogs between cities and open fields.—*C. L. M.*

"STORMS OF COLD" AND THEIR PATHS.

By A. BALDIT.

[Reprinted from Science Abstracts, Sec. A, Aug. 30, 1919, § 995.]

Thunderstorms are usually divided into two classes, (*a*) heat storms and (*b*) storms in depressions. The former are usually local in character, the latter accompany line-squalls, which are experienced in the southern sectors of depressions. The author describes a third type of thunderstorm, namely, "storm of cold," which occurs in a cold zone of air advancing from the north into a region where temperature is high, and upper winds are from the south. In these circumstances cumulo-nimbus clouds developing into thunderstorms are formed on the southern boundary of the cold wave and are carried northward by the upper south wind in a direction opposite to that of the north wind at the surface. Thus the storms travel backwards through the zone of cold air.—*R. C.*

[1] Science Abstracts, July, 1919, pp. 310–311.